

CLAIMS

What is claimed is:

1 1. A series connected buck-boost regulator comprising:
2 a control circuit;
3 a switching circuit for connecting to a source voltage;
4 an output circuit connected to said switching circuit and for outputting a
5 load voltage, wherein
6 said control circuit controls said output circuit and said input circuit for
7 operating said regulator in a plurality modes including:
8 a current limiting (CL) mode;
9 a buck mode; and
10 a boost mode,
11 wherein only a fraction of an output power of said regulator is switched
12 by said switching circuit during one or both of the buck and the
13 boost modes.

1 2. The regulator of claim 1 further comprising a transformer having
2 a primary winding and a center-tapped secondary winding, wherein the center
3 tap of said secondary winding is for connecting to the source voltage, and
4 wherein said primary winding is connected to said switching circuit, and
5 further wherein said secondary winding is connected to said output circuit.

1 3. The regulator of claim 1, wherein said switching circuit includes
2 a first switch, a second switch, a third switch, and a fourth switch in a bridge
3 configuration, and further wherein said output circuit includes a series
4 connected fifth and sixth switch connected to a series connected seventh and
5 eighth switch.

1 4. The regulator of claim 3, wherein, during said boost mode, said
2 control circuit continuously turns on said fifth switch and said sixth switch, and

3 further wherein said control circuit cycles through a plurality of boost states
4 including:
5 a first boost state wherein the first, fourth, and seventh switches are on
6 and further wherein the second, third, and eighth switches are
7 off;
8 a second boost state wherein the seventh and eighth switches are on,
9 and further wherein the first, second, third, and fourth switches
10 are off; and
11 a third boost state wherein the second, third and eighth switches are on
12 and further wherein the first, fourth, and seventh switches are
13 off.

1 5. The regulator of claim 3, wherein, during said buck mode, said
2 control circuit continuously turns on said seventh switch and said eighth
3 switch, and further wherein said control circuit cycles through a plurality of
4 buck states including:
5 a first buck state wherein said first, fourth, and sixth switches are on
6 and further wherein said second, third, and fifth switches are off;
7 a second buck state wherein said fifth and sixth switches are on, and
8 further wherein said first, second, third, and fourth switches are
9 off; and
10 a third buck state wherein said second, third, and fifth switches are on,
11 and further wherein said first, fourth, and sixth switches are off.

1 6. The regulator of claim 3, wherein, during said current limiting
2 mode, said control circuit continuously turns off said first, second, third, and
3 fourth switches, and further wherein said control circuit cycles through a
4 plurality of CL states including:
5 a first CL state wherein said fifth, sixth, seventh, and eighth switches
6 are on; and
7 a second CL state wherein said fifth, sixth, seventh, and eighth
8 switches are off.

1 7. The regulator of claim 3, further comprising a ninth switch
2 connected to said secondary winding which is turned off by said control circuit
3 during said boost and said buck modes, but is turned on during said
4 CURRENT LIMITING mode to short out said secondary winding.

1 8. The regulator of claim 3, wherein each switch has a diode
2 placed in parallel.

1 9. The regulator of claim 8, further comprising:
2 a ninth switch connected to said center tap of said secondary winding
3 which is turned off by said control circuit during said boost and
4 said buck modes, but is turned on during said CURRENT
5 LIMITING mode to short out said secondary winding;
6 a freewheeling diode connected between said output circuit and a
7 ground;
8 a first transformer diode connecting a terminal of said secondary to
9 said ninth switch;
10 a second transformer diode connecting another terminal of said
11 secondary to said ninth switch; and
12 an inductor for connecting said output circuit to a load.

1 10. The regulator of claim 9, wherein, during said boost mode, said
2 control circuit continuously turns on said fifth switch and said sixth switch, and
3 continuously turns off said ninth switch, and further wherein said control circuit
4 cycles through a plurality of boost states including:
5 a first boost state wherein the first, fourth, and seventh switches
6 are on and further wherein the second, third, and eighth
7 switches are off;
8 a second boost state wherein the seventh and eighth switches
9 are on, and further wherein the first, second, third, and
10 fourth switches are off; and

11 a third boost state wherein the second, third and eighth switches
12 are on and further wherein the first, fourth, and seventh
13 switches are off;
14 and wherein, during said buck mode, said control circuit continuously
15 turns on said seventh switch and said eighth switch, and
16 continuously turns off said ninth switch, and further wherein said
17 control circuit cycles through a plurality of buck states including:
18 a first buck state wherein said first, fourth, and sixth switches are
19 on and further wherein said second, third, and fifth
20 switches are off;
21 a second buck state wherein said fifth and sixth switches are on,
22 and further wherein said first, second, third, and fourth
23 switches are off; and
24 a third buck state wherein said second, third, and fifth switches
25 are on, and further wherein said first, fourth, and sixth
26 switches are off;
27 and further wherein, during said CURRENT LIMITING mode, said
28 control circuit continuously turns off said first, second, third, and
29 fourth switches, and continuously turns on said ninth switch, and
30 further wherein said control circuit cycles through a plurality of
31 CL states including:
32 a first CL state wherein said fifth, sixth, seventh, and eighth
33 switches are on; and
34 a second CL state wherein said fifth, sixth, seventh, and eighth
35 switches are off.

1 11. The regulator of claim 1, further comprising a transformer having
2 a primary winding and a center-tapped secondary winding, with the center tap
3 for connecting to the source voltage, wherein
4 said switching circuit includes a first switch, a second switch, a third
5 switch, and a fourth switch in a bridge configuration, said

6 primary winding of said transformer connected to a center of
7 said bridge, and further wherein
8 said output circuit includes a series connected fifth and sixth switch
9 connected to a terminal of said secondary winding and
10 connected to a series connected seventh and eighth switch
11 connected to another terminal of said secondary winding, and
12 also wherein
13 a ninth switch is included in said regulator for shorting out said
14 transformer secondary winding on command from said control
15 circuit.

1 12. The regulator of claim 11, wherein, during said boost mode, said
2 control circuit continuously turns on said fifth switch and said sixth switch, and
3 continuously turns off said ninth switch, and further wherein said control circuit
4 cycles through a plurality of boost states including:
5 a first boost state wherein the first, fourth, and seventh switches
6 are on and further wherein the second, third, and eighth
7 switches are off;
8 a second boost state wherein the seventh and eighth switches
9 are on, and further wherein the first, second, third, and
10 fourth switches are off; and
11 a third boost state wherein the second, third and eighth switches
12 are on and further wherein the first, fourth, and seventh
13 switches are off;
14 and wherein, during said buck mode, said control circuit continuously
15 turns on said seventh switch and said eighth switch, and
16 continuously turns off said ninth switch, and further wherein said
17 control circuit cycles through a plurality of buck states including:
18 a first buck state wherein said first, fourth, and sixth switches are
19 on and further wherein said second, third, and fifth
20 switches are off;

21 a second buck state wherein said fifth and sixth switches are on,
22 and further wherein said first, second, third, and fourth
23 switches are off; and
24 a third buck state wherein said second, third, and fifth switches
25 are on, and further wherein said first, fourth, and sixth
26 switches are off;
27 and further wherein, during said CURRENT LIMITING mode, said
28 control circuit continuously turns off said first, second, third, and
29 fourth switches, and continuously turns on said ninth switch, and
30 further wherein said control circuit cycles through a plurality of
31 CL states including:
32 a first CL state wherein said fifth, sixth, seventh, and eighth
33 switches are on; and
34 a second CL state wherein said fifth, sixth, seventh, and eighth
35 switches are off.

1 13. A series connected buck-boost regulator comprising:
2 a control circuit;
3 a transformer having a primary winding and a center-tapped secondary
4 winding, wherein the center tap of said secondary winding is for
5 connecting to a source voltage;
6 a switching circuit controlled by said control circuit and for pulse-width-
7 modulating the source voltage for inputting into said primary
8 winding, with said switching circuit including four PWM switches
9 connected in a bridge configuration with said primary winding
10 connected to a center of said bridge, wherein each PWM switch
11 has a diode connected in parallel; and
12 an output circuit controlled by said control circuit and connected to said
13 secondary winding for outputting a load voltage, with said output
14 circuit having two pairs of two series connected output switches
15 connected in parallel, wherein each output switch also has a
16 diode connected in parallel.

1 14. The regulator of claim 13, wherein said control circuit controls a
2 duty cycle of said pulse-width-modulation of the source voltage and also
3 drives said output circuit such that said output voltage can be varied in a
4 range from a minimum voltage less than the source voltage to a maximum
5 voltage greater than the source voltage.

1 15. The regulator of claim 14, wherein some substantial fraction of
2 the power input by the source voltage is not pulse-width-modulated by said
3 switching circuit during one or more operating modes.

1 16. The regulator of claim 15, wherein said PWM switches include a
2 first switch, a second switch, a third switch, and a fourth switch, and further
3 wherein said output switches include a fifth switch, a sixth switch, a seventh
4 switch, and an eighth switch,
5 wherein, during said boost mode, said control circuit continuously turns
6 on said fifth switch and said sixth switch, and further wherein
7 said control circuit cycles through a plurality of boost states
8 including:
9 a first boost state wherein the first, fourth, and seventh switches
10 are on and further wherein the second, third, and eighth
11 switches are off;
12 a second boost state wherein the seventh and eighth switches
13 are on, and further wherein the first, second, third, and
14 fourth switches are off; and
15 a third boost state wherein the second, third and eighth switches
16 are on and further wherein the first, fourth, and seventh
17 switches are off;
18 and wherein, during said buck mode, said control circuit continuously
19 turns on said seventh switch and said eighth switch, and further
20 wherein said control circuit cycles through a plurality of buck
21 states including:

22 a first buck state wherein said first, fourth, and sixth switches are
23 on and further wherein said second, third, and fifth
24 switches are off;
25 a second buck state wherein said fifth and sixth switches are on,
26 and further wherein said first, second, third, and fourth
27 switches are off; and
28 a third buck state wherein said second, third, and fifth switches
29 are on, and further wherein said first, fourth, and sixth
30 switches are off;
31 and further wherein, during said current limiting mode, said control
32 circuit continuously turns off said first, second, third, and fourth
33 switches, and further wherein said control circuit cycles through
34 a plurality of CL states including:
35 a first CL state wherein said fifth, sixth, seventh, and eighth
36 switches are on; and
37 a second CL state wherein said fifth, sixth, seventh, and eighth
38 switches are off.

1 16. The regulator of claim 13, further comprising:
2 a first transformer diode connected to a terminal of said secondary
3 winding;
4 a second transformer diode connected to another terminal of said
5 secondary winding; and
6 a transformer shorting switch connected to said center tap of said
7 secondary and also connected to said first and said second
8 transformer diodes for shorting said secondary on command
9 from said control circuit.

1 17. The regulator of claim 16, wherein said PWM switches include a
2 first switch, a second switch, a third switch, and a fourth switch, and further
3 wherein said output switches include a fifth switch, a sixth switch, a seventh
4 switch, and an eighth switch, wherein, during said boost mode,

5 said control circuit continuously turns on said fifth switch and said sixth
6 switch, and continuously turns off said transformer shorting
7 switch, and further wherein said control circuit cycles through a
8 plurality of boost states including:
9 a first boost state wherein the first, fourth, and seventh switches
10 are on and further wherein the second, third, and eighth
11 switches are off;
12 a second boost state wherein the seventh and eighth switches
13 are on, and further wherein the first, second, third, and
14 fourth switches are off; and
15 a third boost state wherein the second, third and eighth switches
16 are on and further wherein the first, fourth, and seventh
17 switches are off;
18 and wherein, during said buck mode, said control circuit continuously
19 turns on said seventh switch and said eighth switch, and
20 continuously turns off said transformer shorting switch, and
21 further wherein said control circuit cycles through a plurality of
22 buck states including:
23 a first buck state wherein said first, fourth, and sixth switches are
24 on and further wherein said second, third, and fifth
25 switches are off;
26 a second buck state wherein said fifth and sixth switches are on,
27 and further wherein said first, second, third, and fourth
28 switches are off; and
29 a third buck state wherein said second, third, and fifth switches
30 are on, and further wherein said first, fourth, and sixth
31 switches are off;
32 and further wherein, during said current limiting mode, said control
33 circuit continuously turns off said first, second, third, and fourth
34 switches, and continuously turns on said transformer shorting
35 switch, and further wherein said control circuit cycles through a
36 plurality of CL states including:

37 a first CL state wherein said fifth, sixth, seventh, and eighth
38 switches are on; and
39 a second CL state wherein said fifth, sixth, seventh, and eighth
40 switches are off.

1 18. The regulator of claim 17, further comprising:
2 a freewheeling diode connected between said output circuit and a
3 ground; and
4 an inductor for connecting said output circuit to a load.

1 19. The regulator of claim 18, wherein said control circuit controls a
2 duty cycle of said pulse-width-modulation of the source voltage and also
3 drives said output circuit such that said output voltage can be varied in a
4 range from a minimum voltage less than the source voltage to a maximum
5 voltage greater than the source voltage.

1 20. The regulator of claim 19, wherein some substantial fraction of
2 the power input by the source voltage is not pulse-width-modulated by said
3 switching circuit during one or more of said modes.